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(11) **EP 1 235 114 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
28.08.2002 Bulletin 2002/35

(51) Int Cl.7: **G03F 7/20**

(21) Application number: **02250999.6**

(22) Date of filing: **13.02.2002**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

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(30) Priority: **14.02.2001 EP 01301257**

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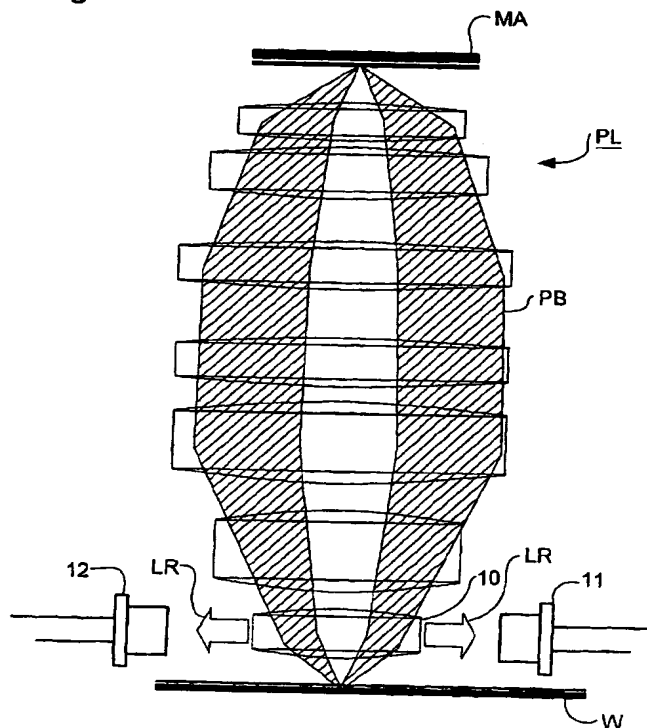
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(54) **Lithographic apparatus and method of manufacturing a device**

(57) A lithographic projection apparatus is provided with a sensor (11, 12) for detecting luminescence radiation (LR) produced in the projection lens system (PL) by the passage of the projection beam (PB). The lumi-

nescence radiation (LR) is indicative of the dose delivered to the substrate (W), and can be detected close to the substrate to avoid errors due to transmission variations in the optical path from the radiation source to the substrate.

Fig. 2



Description

[0001] The present invention relates to a lithographic projection apparatus comprising:

- a radiation system for supplying a projection beam of radiation;
- a support structure for supporting patterning means, the patterning means serving to pattern the projection beam according to a desired pattern;
- a substrate table for holding a substrate; and
- a projection system for projecting the patterned beam onto a target portion of the substrate.

[0002] The term "patterning means" as here employed should be broadly interpreted as referring to means that can be used to endow an incoming radiation beam with a patterned cross-section, corresponding to a pattern that is to be created in a target portion of the substrate; the term "light valve" can also be used in this context. Generally, the said pattern will correspond to a particular functional layer in a device being created in the target portion, such as an integrated circuit or other device (see below). Examples of such patterning means include:

- A mask. The concept of a mask is well known in lithography, and it includes mask types such as binary, alternating phase-shift, and attenuated phase-shift, as well as various hybrid mask types. Placement of such a mask in the radiation beam causes selective transmission (in the case of a transmissive mask) or reflection (in the case of a reflective mask) of the radiation impinging on the mask, according to the pattern on the mask. In the case of a mask, the support structure will generally be a mask table, which ensures that the mask can be held at a desired position in the incoming radiation beam, and that it can be moved relative to the beam if so desired.
- A programmable mirror array. One example of such a device is a matrix-addressable surface having a viscoelastic control layer and a reflective surface. The basic principle behind such an apparatus is that (for example) addressed areas of the reflective surface reflect incident light as diffracted light, whereas unaddressed areas reflect incident light as undiffracted light. Using an appropriate filter, the said undiffracted light can be filtered out of the reflected beam, leaving only the diffracted light behind; in this manner, the beam becomes patterned according to the addressing pattern of the matrix-addressable surface. An alternative embodiment of a programmable mirror array employs a matrix arrangement of tiny mirrors, each of which can be individually tilted about an axis by applying a suitable localized electric field, or by employing piezoelectric actuation means. Once again, the mirrors are matrix-ad-

dressable, such that addressed mirrors will reflect an incoming radiation beam in a different direction to unaddressed mirrors; in this manner, the reflected beam is patterned according to the addressing pattern of the matrix-addressable mirrors. The required matrix addressing can be performed using suitable electronic means. In both of the situations described hereabove, the patterning means can comprise one or more programmable mirror arrays. More information on mirror arrays as here referred to can be gleaned, for example, from United States Patents US 5,296,891 and US 5,523,193, and PCT patent applications WO 98/38597 and WO 98/33096, which are incorporated herein by reference. In the case of a programmable mirror array, the said support structure may be embodied as a frame or table, for example, which may be fixed or movable as required.

A programmable LCD array. An example of such a construction is given in United States Patent US 5,229,872, which is incorporated herein by reference. As above, the support structure in this case may be embodied as a frame or table, for example, which may be fixed or movable as required.

For purposes of simplicity, the rest of this text may, at certain locations, specifically direct itself to examples involving a mask and mask table; however, the general principles discussed in such instances should be seen in the broader context of the patterning means as hereabove set forth.

[0003] Lithographic projection apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In such a case, the patterning means may generate a circuit pattern corresponding to an individual layer of the IC, and this pattern can be imaged onto a target portion (e.g. comprising one or more dies) on a substrate (silicon wafer) that has been coated with a layer of radiation-sensitive material (resist). In general, a single wafer will contain a whole network of adjacent target portions that are successively irradiated via the projection system, one at a time. In current apparatus, employing patterning by a mask on a mask table, a distinction can be made between two different types of machine. In one type of lithographic projection apparatus, each target portion is irradiated by exposing the entire mask pattern onto the target portion in one go; such an apparatus is commonly referred to as a wafer stepper. In an alternative apparatus — commonly referred to as a step-and-scan apparatus — each target portion is irradiated by progressively scanning the mask pattern under the projection beam in a given reference direction (the "scanning" direction) while synchronously scanning the substrate table parallel or anti-parallel to this direction; since, in general, the projection system will have a magnification factor M (generally < 1), the speed V at which the substrate table is scanned will be a factor M times that at which the mask table is scanned. More in-

formation with regard to lithographic devices as here described can be gleaned, for example, from US 6,046,792, incorporated herein by reference.

[0004] In a manufacturing process using a lithographic projection apparatus, a pattern (e.g. in a mask) is imaged onto a substrate that is at least partially covered by a layer of radiation-sensitive material (resist). Prior to this imaging step, the substrate may undergo various procedures, such as priming, resist coating and a soft bake. After exposure, the substrate may be subjected to other procedures, such as a post-exposure bake (PEB), development, a hard bake and measurement/inspection of the imaged features. This array of procedures is used as a basis to pattern an individual layer of a device, e.g. an IC. Such a patterned layer may then undergo various processes such as etching, ion-implantation (doping), metallization, oxidation, chemo-mechanical polishing, etc., all intended to finish off an individual layer. If several layers are required, then the whole procedure, or a variant thereof, will have to be repeated for each new layer. Eventually, an array of devices will be present on the substrate (wafer). These devices are then separated from one another by a technique such as dicing or sawing, whence the individual devices can be mounted on a carrier, connected to pins, etc. Further information regarding such processes can be obtained, for example, from the book "Microchip Fabrication: A Practical Guide to Semiconductor Processing", Third Edition, by Peter van Zant, McGraw Hill Publishing Co., 1997, ISBN 0-07-067250-4, incorporated herein by reference.

[0005] For the sake of simplicity, the projection system may hereinafter be referred to as the "lens"; however, this term should be broadly interpreted as encompassing various types of projection system, including refractive optics, reflective optics, and catadioptric systems, for example. The radiation system may also include components operating according to any of these design types for directing, shaping or controlling the projection beam of radiation, and such components may also be referred to below, collectively or singularly, as a "lens". Further, the lithographic apparatus may be of a type having two or more substrate tables (and/or two or more mask tables). In such "multiple stage" devices the additional tables may be used in parallel, or preparatory steps may be carried out on one or more tables while one or more other tables are being used for exposures. Dual stage lithographic apparatus are described, for example, in US 5,969,441 and WO 98/40791, incorporated herein by reference.

[0006] In a lithographic projection process it is important to control accurately the dose (i.e. amount of energy per unit area integrated over the duration of the exposure) delivered to the resist. Known resists are designed to have a relatively sharp threshold, whereby the resist is exposed if it receives an amount of energy per unit area above the threshold but remains unexposed if the amount of received energy is less than the threshold.

This is used to produce sharp edges in the features in the developed resist, even when diffraction effects cause a gradual tail-off in intensity of the projected images at feature edges. If the beam intensity is substantially incorrect, the exposure intensity profile can cross the resist threshold at the wrong point. Dose control is thus crucial to correct imaging.

[0007] In a known lithographic apparatus dose control is done by monitoring the beam intensity at a point in the radiation system and calibrating the absorption of the apparatus between that point and the substrate level. Monitoring the beam intensity is performed using a partially transmissive mirror to divert a known fraction of the projection beam in the radiation system to an energy sensor. The energy sensor measures the energy in the known fraction of the beam and so enables the beam energy at a given point in the radiation system to be determined. The calibration of the absorption of the apparatus, downstream of the partially transmissive mirror, is done by replacing the substrate by an energy sensor for a series of calibration runs. The output of the energy sensor effectively measures variations in the output of the radiation source and is combined with the calibration results of the absorption of the downstream parts of the apparatus to predict the energy level at substrate level. In some cases the prediction of the energy level at substrate level may take account of parameters of the exposure, e.g. radiation system settings. The exposure parameters, e.g. duration or scanning speed, and/or the output of the radiation source can then be adjusted to deliver the desired dose to the resist.

[0008] Whilst the known method of dose control takes account of variations in the output of the radiation source and deals well with predictable variations in absorption downstream of the energy sensor, not all variations in absorption are easily or accurately predictable. This is particularly the case for apparatus using exposure radiation of shorter wavelengths, which are essential to reduce the size of the smallest features that can be imaged, such as 193 nm, 157nm, or 126nm. Such wavelengths are heavily absorbed by air and many other gases so that lithographic apparatus making use of them must be either flushed with non-absorbing gases or evacuated. Any variations in the composition of the flushing gas or leaks from the outside can result in significant and unpredictable variations in the absorption of the beam in the downstream parts of the apparatus and hence of the dose delivered to the resist.

[0009] An object of the present invention is therefore to provide an improved dose sensing and control system which avoids or alleviates the problems of known energy sensors and dose control systems.

[0010] This and other objects are achieved according to the invention in a lithographic apparatus as specified in the opening paragraph, characterized by further comprising:

a sensor arranged to detect luminescence radiation

produced in said projection system by the passage of said projection beam.

[0011] The sensor, which may comprise one or more photodiodes, for example, detects luminescence radiation caused by the interaction of the projection beam radiation, such as ultraviolet radiation, with the material of the projection system, such as calcium fluoride or quartz lens elements. The luminescence radiation intensity is indicative of the dose being delivered to the substrate. Unlike other dose sensors, no part of the projection beam is additionally blocked or diverted, because the luminescence radiation is an intrinsic property of the interaction of the projection beam radiation and the lens. Furthermore, the luminescence radiation can be measured from the projection system very close to the substrate, and therefore, unlike other dose measurements, is not prone to errors due to transmission variations in the optical path from the radiation source to the substrate. The luminescence radiation can be measured at the side of or beyond the end of the projection system and therefore can avoid occupying the very limited space between the projection system and the substrate.

[0012] According to one preferred embodiment, the sensor comprises a plurality of detectors. These can capture the luminescence radiation emitted in different directions and can be summed to produce a signal. According to another embodiment, a radiation guide is provided to direct the luminescence radiation emitted in a plurality of directions all to a single detector. This reduces the cost and wiring complexity of a plurality of detectors, and enables the single detector to be located remote from the projection system to reduce the space overhead and to facilitate exchangeability of the detector.

[0013] The particular illumination mode and patterning of the projection beam can result in inhomogeneous generation of luminescence radiation. Thus the luminescence radiation in particular directions can vary between different illumination settings and patterns even though the actual dose on the substrate is the same. In either of the above preferred embodiments this problem can be avoided, because the luminescence radiation emitted in a plurality of directions is detected (using a plurality of detectors or using a waveguide arrangement and a single detector), so the resulting signal can be indicative of the actual dose regardless of the particular illumination mode or patterning of the projection beam.

[0014] According to a further aspect of the invention there is provided a device manufacturing method comprising the steps of:

- providing a substrate that is at least partially covered by a layer of radiation-sensitive material;
- providing a projection beam of radiation using a radiation system;
- using patterning means to endow the projection beam with a pattern in its cross-section;

- projecting the patterned beam of radiation onto a target area of the layer of radiation-sensitive material on said substrate,

characterized by the step of:

detecting luminescence radiation produced in said projection system by the passage of said projection beam.

[0015] Although specific reference may be made in this text to the use of the apparatus according to the invention in the manufacture of ICs, it should be explicitly understood that such an apparatus has many other possible applications. For example, it may be employed in the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, liquid-crystal display panels, thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms "wafer" or "die" in this text should be considered as being replaced by the more general terms "substrate" and "target area", respectively.

[0016] In the present document, the terms radiation and beam are used to encompass all types of electromagnetic radiation, but specifically ultraviolet radiation, e.g. with a wavelength of 365, 248, 193, 157 or 126 nm.

[0017] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which:

Figure 1 depicts a lithographic projection apparatus according to an embodiment of the invention;

Figure 2 is a schematic longitudinal cross-section illustrating the projection lens system and part of the luminescence radiation sensor according to a first embodiment of the invention;

Figure 3 is a schematic transverse cross-section of the sensor of the embodiment Fig 2;

Figure 4 is a schematic transverse cross-section of the sensor of a second embodiment of the invention; and

Figure 5 is a schematic longitudinal cross-section of part of the projection lens and luminescence radiation sensor according to a third embodiment of the invention.

[0018] In the Figures, corresponding reference symbols indicate corresponding parts.

Embodiment 1

[0019] Figure 1 schematically depicts a lithographic projection apparatus according to a particular embodiment of the invention. The apparatus comprises:

a radiation system LA, Ex, IL, for supplying a projection beam PB of radiation (e.g. UV radiation);

a first object table (mask table) MT for holding a mask MA (e.g. a reticle), and connected to first positioning means for accurately positioning the mask with respect to item PL;

a second object table (substrate table) WT for holding a substrate W (e.g. a resist-coated silicon wafer), and connected to second positioning means for accurately positioning the substrate with respect to item PL;

a projection system ("lens") PL (e.g. a quartz and/or CaF_2 lens system or a catadioptric system comprising lens elements made from such materials) for imaging an irradiated portion of the mask MA onto a target portion C (comprising one or more dies) of the substrate W.

[0020] As here depicted, the apparatus is of a transmissive type (i.e. has a transmissive mask). However, in general, it may also be of a reflective type, for example (with a reflective mask). Alternatively, the apparatus may employ another kind of patterning means, such as a programmable mirror array of a type as referred to above.

[0021] The radiation system comprises a source LA (e.g. a UV laser) that produces a beam of radiation. This beam is fed into an illumination system (illuminator) IL, either directly or after being passed through conditioning means, such as a beam expander Ex, for example. The illuminator IL comprises adjusting means AM for setting the outer and/or inner radial extent (commonly referred to as σ -outer and σ -inner, respectively) of the intensity distribution in the beam. In addition, it will generally comprise various other components, such as an integrator IN and a condenser CO. In this way, the beam PB impinging on the mask MA has a desired uniformity and intensity distribution in its cross-section.

[0022] It should be noted with regard to Figure 1 that the source LA may be within the housing of the lithographic projection apparatus (as is often the case when the source LA is a mercury lamp, for example), but that it may also be remote from the lithographic projection apparatus, the radiation beam which it produces being led into the apparatus (e.g. with the aid of suitable directing mirrors); this latter scenario is often the case when the source LA is an excimer laser. The current invention and Claims encompass both of these scenarios.

[0023] The beam PB subsequently intercepts the mask MA which is held in a mask holder on a mask table MT. Having traversed the mask MA, the beam PB passes through the lens PL, which focuses the beam PB onto a target portion C of the substrate W. With the aid of the second positioning means (and interferometric measuring means IF), the substrate table WT can be moved accurately, e.g. so as to position different target portions C in the path of the beam PB. Similarly, the first positioning means can be used to accurately position the mask MA with respect to the path of the beam PB, e.g. after mechanical retrieval of the mask MA from a mask

library, or during a scan. In general, movement of the object tables MT, WT will be realized with the aid of a long stroke module (course positioning) and a short stroke module (fine positioning), which are not explicitly depicted in Figure 1. However, in the case of a wafer stepper (as opposed to a step-and-scan apparatus) the mask table MT may just be connected to a short stroke actuator, or may be fixed.

[0024] The depicted apparatus can be used in two different modes:

1. In step mode, the mask table MT is kept essentially stationary, and an entire mask image is projected in one go (i.e. a single "flash") onto a target portion C. The substrate table WT is then shifted in the x and/or y directions so that a different target portion C can be irradiated by the beam PB;

2. In scan mode, essentially the same scenario applies, except that a given target portion C is not exposed in a single "flash". Instead, the mask table MT is movable in a given direction (the so-called "scan direction", e.g. the x direction) with a speed v , so that the projection beam PB is caused to scan over a mask image; concurrently, the substrate table WT is simultaneously moved in the same or opposite direction at a speed $V = Mv$, in which M is the magnification of the lens PL (typically, $M = 1/4$ or $1/5$). In this manner, a relatively large target portion C can be exposed, without having to compromise on resolution.

[0025] Figure 2 shows a longitudinal cross-section of the projection lens PL between the mask MA and the wafer W. The projection lens PL consists of a stack of many individual lens elements. A pair of detectors 11, 12, such as photodiodes, are positioned on diametrically opposite sides of the projection lens element 10 which is closest to the wafer W. A projection beam PB passes through projection lens PL. If the projection beam PB has a wavelength of, for example, 193 nm, then the material of the projection lens element 10 can be, for example, calcium fluoride or quartz. If the radiation of the projection beam PB has a wavelength of, for example, 157 nm, then the material of the projection lens 10, can be, for example, calcium fluoride (optionally in the presence of mirrors, so as to comprise a catadioptric system). When either of these materials of the projection lens element 10 is irradiated by the laser light of the projection beam PB, some luminescence radiation is produced, shown schematically by the arrows labeled LR. The luminescence radiation is, for example, typically light in the green to yellow part of the visible spectrum. The material of the projection lens element 10 interacts with the high energy, short wavelength, laser radiation of the projection beam PB to convert a tiny proportion of it to longer wavelength luminescence radiation LR. The material of the projection lens element 10 is substantially transparent to the luminescence radiation LR.

In the case of a laser source LA, the amplitude of the luminescence radiation is proportional (linearly or almost linearly) to the pulse energy of the laser pulses of the projection beam PB. The detectors 11, 12 are sensitive to the luminescence radiation LR and produce an output current, and in this way the amplitude of the projection beam laser pulses can be measured by measuring the output current signal from the detectors 11, 12. This measurement also gives an indication of the exposure dose on the wafer because the projection lens element 10 immediately precedes the wafer W in the optical path.

[0026] Whichever portions of the projection lens element 10 the projection beam PB passes through act as luminescence sources within the projection lens element 10. As can be seen in Figure 2, the position of the luminescence sources strongly depends on the illumination mode, i.e. the distribution of intensity across the projection beam PB and lens element 10. To avoid this potential source of detected signal variation, more than one detector, such as the pair 11, 12 shown in Figure 2 are used. However, even more satisfactory results can be obtained according to this embodiment using the arrangement shown in Figure 3, in which a ring of eight detectors 11 - 18 are arranged circumferentially spaced apart around the periphery of the projection lens element 10.

[0027] A ring circuit shown schematically by the wires 20, 21, is used to connect all the detectors 11 - 18 in parallel. This arrangement sums the signals from all of the detectors 11 - 18 to produce an overall sensor signal.

Embodiment 2

[0028] Figure 4 shows an arrangement which is essentially the same as that of Figure 3, except that the detectors have been replaced by reflective elements 30 - 38 which direct the luminescence radiation to a single detector 39. The inner wall 40 of the projection lens system is also reflective and together with the reflective elements 30 - 38 forms a reflecting radiation guide. As shown in Figure 4, one particular reflective element 36 receives luminescence radiation from a wedge-shaped portion 42 of the lens element 10 and reflects it round the radiation guide, as shown by the hatched region 44 to the detector 39. The luminescence radiation directed by all of the other reflective elements has been omitted for clarity, but its path is simply shown by the arrows.

[0029] Other suitable radiation guides can be used, such as optical fibres, to direct the luminescence radiation from different portions of the projection lens element 10 to the single detector 39.

Embodiment 3

[0030] This embodiment can be the same as the preceding embodiments in all respects except that, as shown in Figure 5, the luminescence radiation LR from

the projection lens element 10 is viewed from outside the lens hood 50, which is incorporated into the machine for gas purging reasons. This simplifies the installation of the luminescence radiation sensor and also improves its subsequent accessibility.

[0031] Although in Figure 5 detectors 11 and 12 are shown, as in the first embodiment, it is, of course, possible to replace these by a radiation guide and a single detector as in the second embodiment described above.

[0032] In this third embodiment, it will be seen that the luminescence radiation sensor system is located forward of the projection lens element 10 which is closest to the wafer W, rather than being provided in the same plane as the projection lens element 10 as shown in Figures 3 and 4. The sensor system detects luminescence radiation emitted from the face of the projection lens element 10 closest to the wafer W. By use of appropriate radiation guides and/or reflective elements, the detectors or detector of this sensor system could, of course, be located elsewhere outside of the lens hood 50.

[0033] In all of the above embodiments of the invention, the signal from the luminescence radiation sensor system can be integrated over all pulses in the exposure to produce an integrated sensor signal, instead of using the individual pulses. Alternatively, the calculated dose is stored in a memory which holds a history of the doses delivered by previous pulses. Since the exposure of a given target area on the substrate is built up from the doses delivered by a plurality of pulses, the history of previous pulses making up the current exposure is used to determine any necessary correction to be applied to subsequent pulses of the exposure. In either case, any necessary corrections and adjustments for dose control can be effected, for example, by adjustment of the intensity of the radiation source LA, by adjusting the opening time of a shutter, by adjusting the degree of opening of an iris located at an aperture plane of the illumination system, by adjusting the pulse repetition rate, by adjusting the scanning speed in a step-and-scan apparatus, or any suitable combination of these parameters.

[0034] The luminescence radiation sensor can, of course, be used in addition to an energy sensor in the illumination system, and both can be used to support dose control. The luminescence radiation sensor can give useful information about what is happening around wafer level during exposures. The luminescence radiation sensor can, for example, be used for fine-tuning the laser pulse set point during scan. Furthermore, the luminescence of the projection lens elements can vary over time, particularly over long time scales such as the lifetime of the lens. Parameters can be included in the dose control setting of the lithographic projection apparatus to compensate for this drift in the luminescence radiation detected by the sensor.

[0035] Whilst specific embodiments of the invention have been described above, it will be appreciated that the invention may be practiced otherwise than as described. The description is not intended to limit the in-

vention.

Claims

1. A lithographic projection apparatus comprising:

a radiation system for providing a projection beam of radiation;
 patterning means, for patterning the projection beam according to a desired pattern;
 a substrate table for holding a substrate;
 a projection system for imaging the patterned beam onto a target portion of the substrate,

characterized by further comprising:

a sensor arranged to detect luminescence radiation produced in said projection system by the passage of said projection beam.

2. Apparatus according to claim 1, wherein said sensor is arranged to detect luminescence radiation from at least one lens element of said projection system.
3. Apparatus according to claim 2, wherein said sensor is arranged to detect luminescence radiation from at least the lens element of said projection system which is closest to the substrate table.
4. Apparatus according to claim 1, 2 or 3, wherein said sensor comprises at least one detector.
5. Apparatus according to claim 4, wherein the or each detector is provided with a radiation guide to direct the luminescence radiation to the or each detector.
6. Apparatus according to claim 5, wherein said radiation guide comprises at least one of: reflective elements; and optical fibers.
7. Apparatus according to claim 5 or 6, wherein the or each detector is remote from said projection system.
8. Apparatus according to any one of claims 4 to 7, wherein the or each detector comprises a photodiode or a photomultiplier tube.
9. Apparatus according to any one of claims 4 to 8, comprising a plurality of detectors and an arrangement to sum their outputs.
10. Apparatus according to any one of the preceding claims, wherein said sensor comprises a plurality of detectors arranged around the periphery of a lens element of said projection system and arranged to

detect luminescence radiation from that lens element.

11. Apparatus according to any one of the preceding claims, wherein said sensor comprises a plurality of reflective elements arranged around the periphery of a lens element of said projection system and arranged to direct luminescence radiation from that lens element to a single detector.

12. Apparatus according to any one of the preceding claims, wherein said sensor comprises at least one detector arranged to detect luminescence radiation emitted from the face of the projection lens element closest to the substrate table.

13. Apparatus according to any one of the preceding claims, further comprising an integrator for integrating over time the output of said sensor.

14. Apparatus according to any one of the preceding claims, further comprising a controller responsive to the output of said sensor for controlling the dose delivered by said projection beam in an exposure.

15. Apparatus according to any one of the preceding claims, wherein said radiation system is adapted to supply a projection beam of radiation having a wavelength of less than 200nm.

16. Apparatus according to any one of the preceding claims, wherein said projection system comprises at least one lens element made of one of calcium fluoride and quartz, and wherein said luminescence radiation is light in the visible spectrum.

17. An apparatus according to any one of the preceding claims, wherein the patterning means comprise a mask table for holding a mask

18. A device manufacturing method comprising the steps of:

providing a substrate that is at least partially covered by a layer of radiation-sensitive material;
 providing a projection beam of radiation using a radiation system;
 using patterning means to endow the projection beam with a pattern in its cross-section;
 projecting the patterned beam of radiation onto a target area of the layer of radiation-sensitive material of said substrate,

characterized by the step of:

detecting luminescence radiation produced in said projection system by the passage of said

projection beam.

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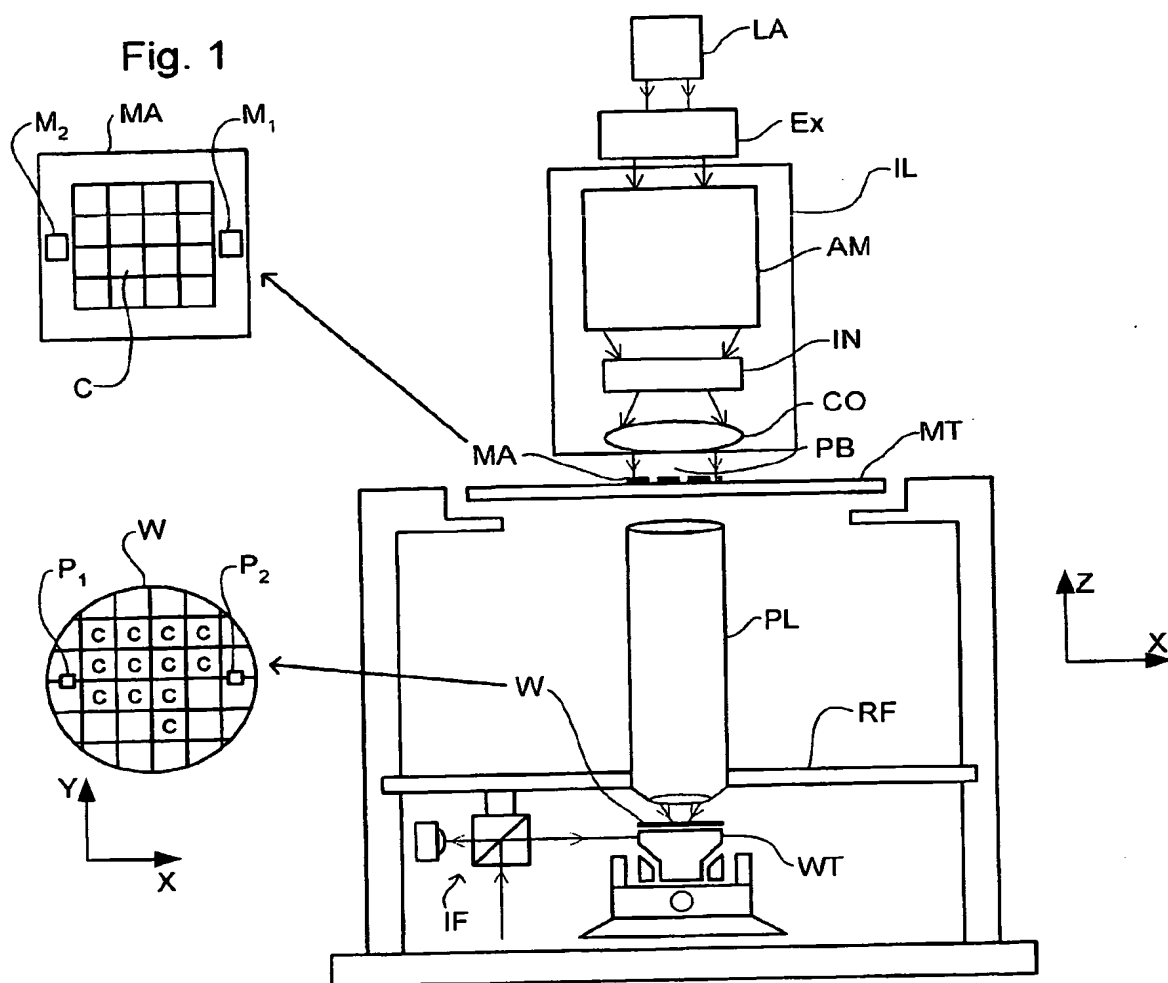


Fig. 2

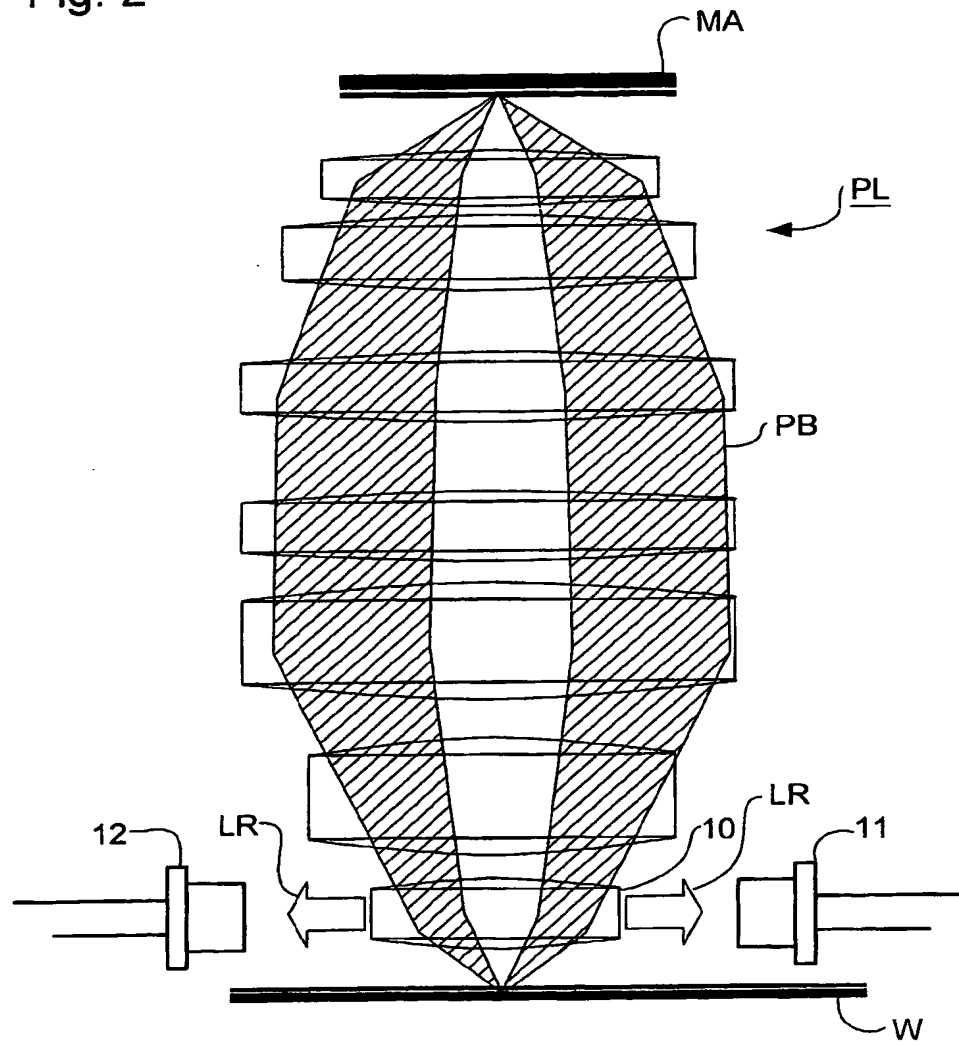


Fig. 3

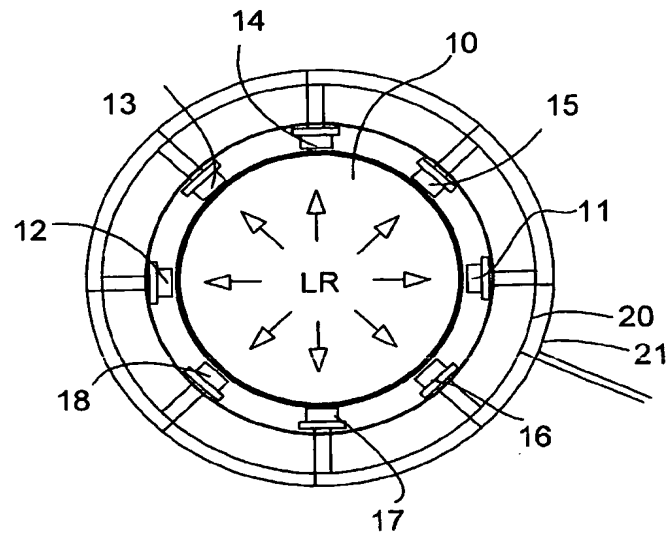


Fig. 4

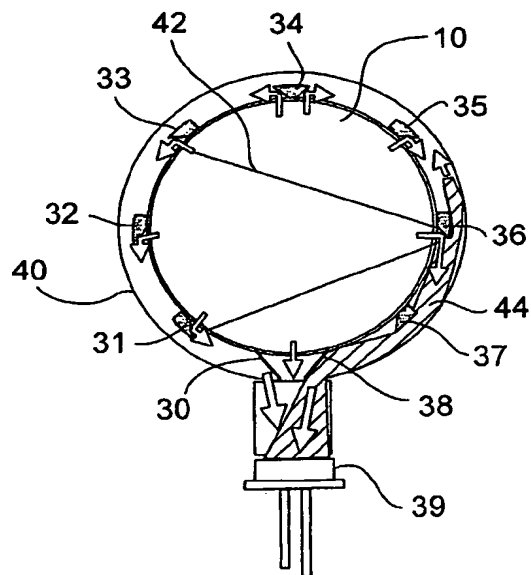
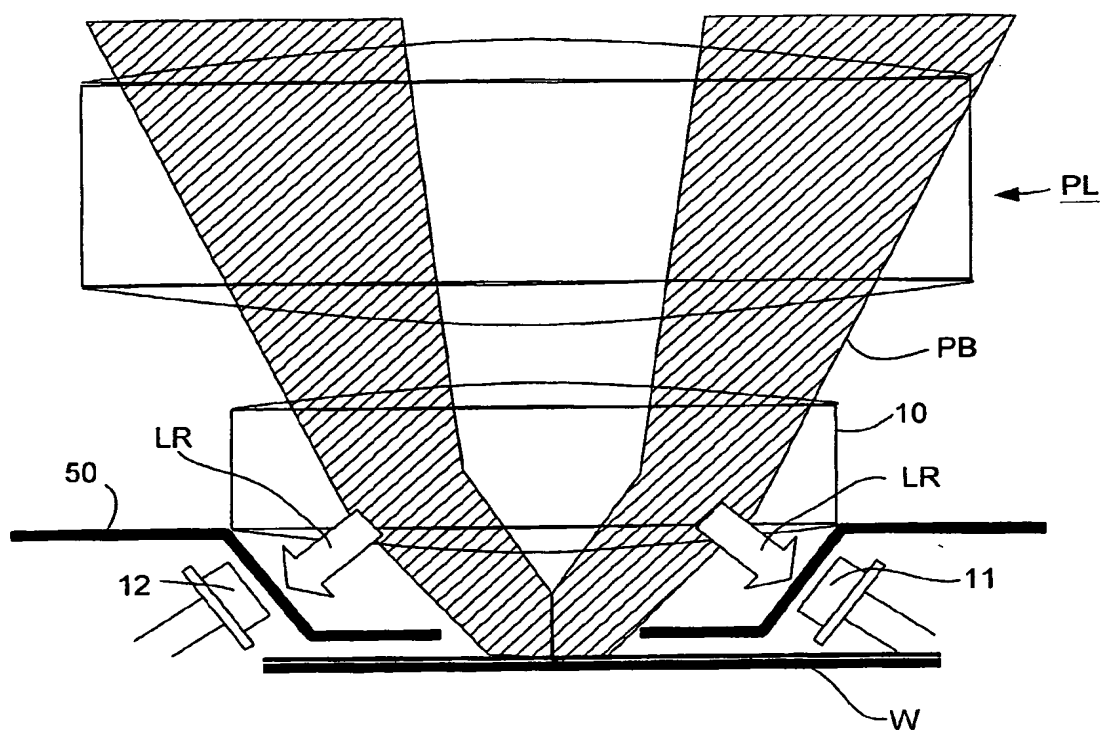


Fig. 5





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 02 25 0999

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	PATENT ABSTRACTS OF JAPAN vol. 012, no. 063 (E-585), 25 February 1988 (1988-02-25) -& JP 62 204527 A (HITACHI LTD), 9 September 1987 (1987-09-09) * abstract; figures *	1-8, 12-14, 16-18	G03F7/20
X	US 5 081 635 A (WAKABAYASHI OSAMU ET AL) 14 January 1992 (1992-01-14) * column 1, line 6 - line 31 * * column 18, line 47 - column 19, line 19; figure 22 *	1,4,8, 13-18	
X	EP 0 445 871 A (ASM LITHOGRAPHY BV) 11 September 1991 (1991-09-11) * abstract * * column 26, line 42 - line 54 * * figures 4,9 *	1,4,8, 16-18	
X	US 4 929 083 A (BRUNNER TIMOTHY A) 29 May 1990 (1990-05-29) * abstract; figures 1,2 * * column 4, line 54 - column 5, line 17 *	1,4,8, 16-18	TECHNICAL FIELDS SEARCHED (Int.Cl.7)
X	EP 1 039 510 A (NIPPON KOGAKU KK) 27 September 2000 (2000-09-27) * paragraph '0036! * * paragraph '0115! - paragraph '0116! * * paragraph '0155!; claim 14; figure 9 *	1,4,8, 14,15, 17,18	G03F H01J
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 4 July 2002	Examiner Heryet, C
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Patent document cited in search report		Publication date	Patent family member(s)		Publication date
JP 62204527	A	09-09-1987	NONE		
US 5081635	A	14-01-1992	JP	1053589 A	01-03-1989
			JP	2649357 B2	03-09-1997
			JP	1057774 A	06-03-1989
			DE	3890693 T0	19-07-1990
			WO	8902175 A1	09-03-1989
EP 0445871	A	11-09-1991	NL	9000503 A	01-10-1991
			EP	0992855 A1	12-04-2000
			EP	0445871 A1	11-09-1991
			JP	2052851 C	10-05-1996
			JP	6163348 A	10-06-1994
			JP	7093256 B	09-10-1995
US 4929083	A	29-05-1990	NONE		
EP 1039510	A	27-09-2000	AU	1053199 A	07-06-1999
			EP	1039510 A1	27-09-2000
			US	6359678 B1	19-03-2002
			WO	9926278 A1	27-05-1999
			JP	11219900 A	10-08-1999
			JP	11243052 A	07-09-1999

EPO FORM P/0459

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